On the other hand, the idea of simply adding on an extra step or two to an already existing process of manufacturing phosphoric acid was tempting. Prodigious amounts of phosphate rock are mined and processed each year, producing over 10 million tons of phosphoric acid.

In the most commonly practiced "wet" process, the rock is digested by sulfuric acid, during which the uranium is dissolved in the solution. At this point in the process the uranium is, in effect, mined and dissolved "for free." Hence, its recovery as a byproduct is potentially economic. All that was required was an efficient separation process.

The key to an efficient separation process was the development of a special chemical, called an "extractant," which had a strong preference for the uranium atoms as found in the acid solution. To be effective, the extractant's attraction had to be sufficiently strong to cause the uranium to separate from its unwanted neighbors in the acid solution and chemically bond to it. The extractant then had to be easily removed from the solution and persuaded under different conditions to let go of the uranium, so that it could be recycled to pick up another load. Finally, it had to be prepared at an acceptable cost and remain stable for many repeated cycles of gathering and releasing.

At Oak Ridge National Laboratory, the study of uranium chemistry had long been a topic of research. This experience uniquely positioned Basic Energy Sciences researchers there to tackle this problem.

Earlier research had demonstrated, for example, that the strength of chemical bonding between uranium and certain types of extractants is highly sensitive to the number of electrons uranium shares with other elements. It was well known that these electrons can number either six or four, and that uranium can be made to favor one form or the other through interactions with certain chemical agents.

An agent that converts uranium to a form that shares four electrons (the tetravalent form of uranium) is called a reducing agent. An agent that converts uranium to a form that shares six electrons (the hexavalent form) is called an oxidizing agent.

Given this knowledge, the researchers hypothesized that one or more extractants might be found that bonded strongly to one form, and weakly to the other, providing a means to first attract, and then release the uranium. One such extractant had been developed in the 1950's, but proved to have a number of operating difficulties, including low stability and insufficient affinity for uranium. This resulted in recovered products of poor quality. Even so, the research showed some promise, and the researchers began in 1967 to experiment with similar approaches.

The concept of extracting a valuable mineral from solution by adjusting its valence was novel to the commercial extraction industry at that time. It was a logical step for Basic Energy Sciences researchers, however, with years of experience working with uranium chemistry.

Five years later, in 1972, these researchers announced that they had developed a combination of two stable extractants with improved capabilities for stripping uranium from the phosphoric acid production process. Together, they were known by the acronym, DEPA-TOPO, after the two extractants, *D*i 2-*E*thylhexl *P*hosphoric *A*cid and *T*ri-n-*O*ctyl *P*hosphine *O*xide.

The actions of the two extractants were found to be synergistic in that they worked together much more effectively than either did individually. So well did they work as a team that almost 90 percent of the uranium originally in the phosphate rock solution was recovered when the process was used.

As the Basic Energy Sciences researchers had hypothesized, it was the hexavalent form of uranium that DEPA-TOPO preferred. The phosphoric acid solution was first treated with an oxidizing agent, such as hydrogen peroxide or oxygen gas, to convert all the dissolved uranium to the hexavalent form. Then a kerosene solution containing the DEPA-TOPO extractants (kerosene was chosen because it does not mix well with acids) pulled the uranium into the kerosene solution and left behind the uranium-depleted phosphoric acid.

In the second or stripping step, the extractants were persuaded to let go of the uranium by bringing them into contact with a small amount of acid to which a reducing agent had been added. This reducing agent converted the hexavalent form of uranium back to the tetravalent form, which DEPA-TOPO extractants did not favor. This allowed the uranium to be stripped from the kerosene solution containing the extractants and put back into a new separated stream of acid solution.